IODP Expedition 398: Hellenic Arc Volcanic Field

Site U1598 Summary

Background and Scientific Objectives

Site U1598 is located ~8 km northwest of Christiana Island and ~20 km southwest of Santorini in a water depth of 521 meters below sea level (mbsl). The drill site targeted the Pliocene–Quaternary volcano-sedimentary fill of the Christiana Basin in two holes: Hole U1598A to a depth of 80 meters below seafloor (mbsf) and Hole U1598B to 99 mbsf.

Christiana Basin formed by subsidence along an ENE–WSW fault system in the Pliocene to early Pleistocene, before the changing tectonic regime activated the current northeast–southwest rift system in which the Christiana-Santorini-Kolumbo (CSK) volcanic field lies. Christiana Basin is deeper than the Anhydros and Anafi Basins; its volcano-sedimentary fill potentially records the earlier volcanic history of the CSK volcanic field (including the products of Christiana and early Santorini), as well as younger Santorini and possibly Milos Volcano to the west along the Aegean Volcanic Arc. The now-extinct Christiana Volcano produced lavas and tuffs of unknown ages, but an ignimbrite found on Christiana, Santorini, and the nonvolcanic island of Anafi, called the Lower Christiana Tuff, has the geochemical fingerprint of Christiana magmas and has been dated using the fission track method on zircon at ~1 Ma.

Site U1598 was chosen to complement the previously drilled Site U1591. The aim was to target a thick pumice layer found at Site U1591 (top about 65 mbsf)—for which we had insufficient recovery for our scientific aims—in order to increase our recovery of the interval. This pumice layer was thought to be possibly the submarine equivalent of the Lower Christiana Tuff. The site address scientific objectives 1–4 and 6 of the Expedition 398 *Scientific Prospectus*.

Operations

The vessel arrived at Site U1598 (proposed Site CSK-14A) on 24 January 2023 at 1945 h. The vessel was under full dynamic positioning (DP) control at 2015 h, ending the transit and marking the start of Site U1598.

The advanced piston corer/extended piston corer (APC/XCB) bottom-hole assembly (BHA) with a bit was assembled. Hole U1598A (36°18.2937′N, 25°7.7155′E) was spudded at 2350 h on 24 January from 527.0 meters below rig floor (mbrf). Core U1598A-1H recovered 3.7 m, establishing the seafloor at 521.5 mbsl. Coring continued into 25 January to U1598A-8H from 60.7 mbsf. The switch was made to the half-length advanced piston corer (HLAPC) with Cores U1598A-9F to 10F at 79.6 mbsf. High torque was observed when drilling; the drill string was worked, but to be conservative, the decision was made to pull out of the hole. The drill string

was tripped up and out of the hole with the bit clearing the seafloor at 0715 h, ending Hole U1598A.

The vessel was offset 50 m southwest of Hole U1598A. Hole U1598B (36°18.2747′N, 25°7.6929′E) was spudded at 0805 h, using the offset water depth of 532.8 mbrf. A drill ahead section was completed to 75.6 mbsf. At 1015 h on 25 January, coring commenced with the HLAPC from Cores U1598B-2H to 6F at 98.8 mbsf, the final depth for Hole U1598B. Excessive torque was again observed, and the decision made to abandon the hole.

The string was pulled out of the hole with the top drive and the bit cleared the seafloor at 1430 h. The top drive was racked back, and the pipe trip up continued to 127 mbrf. The bit cleared the rotary table at 1645 h. The rig floor was secured. The thrusters were raised starting at 1720 h. The vessel was switched to bridge control at 1725 h. All thrusters were up and secured and the sea passage to Site U1599 started at 1730 h on 25 January, ending Site U1598.

Principal Results

Cores from two consecutively cored holes at Site U1598 (Holes U1598A and U1598B) recovered a stratigraphy from 0 to 95.68 mbsf. The recovered material is sedimentary and unlithified in Holes U1598A and U1598B, and characterized by dominantly volcanic lithologies (ash/tuff, lapilli-ash, lapilli, and tuffaceous mud/ooze) and less nonvolcanic sediments, like calcareous mud and ooze. Smear slides for microscopic analyses were prepared to confirm macroscopic descriptions of distinct lithology changes at the section level, such as the identification of vitric particles in tuffaceous lithologies or crystals in ash layers. The succession of tuffaceous muds/oozes and volcanic layers defines three subunits (Ia, Ib, and Ic). X-ray diffraction (XRD) data were obtained from six interstitial water (IW) squeeze cake sediment residues from Hole U1598A.

Structural geology analyses at Site U1598 included the description of cores retrieved from Hole U1598A. A total of 28 structures were measured, and most of those measurements derived from relatively consolidated intervals. Observed and measured structures on cores are all beddings. Where possible, we corrected the measurements of planar and linear structures to true geographic coordinates using paleomagnetic data. The precision of shipboard measurements equals that of terrestrial measurements in structural geology and accounts for numbers in the range of 1° to 2° per single measurement. The accumulation of single measurements within groups of identified structures are concentrated around means typically giving confidence intervals with errors much smaller than for single measurements. Deformation related to drilling and core recovery was noted, but not recorded. Here we describe and provide examples of the features that were recorded.

Planktic and benthic foraminifers and calcareous nannofossils were examined from eight core catcher samples and additional split-core samples from Holes U1598A and U1598B to develop a

shipboard biostratigraphic framework for Site U1598. Additionally, benthic foraminifers provided data on paleowater depths, downslope reworking, and possible dissolution.

Holes U1598A and U1598B overlap between 75.3 and 79.4 mbsf. However, in this short interval no reliable correlation could be identified. Therefore, no affine ties were generated and no shifts were applied to the cores. To be able to combine measurements easily from both holes, the stratigraphic correlators nevertheless generated a quasisplice, which simply represents a combination of the cores from both holes without any shifts.

The typical increases of bulk density, *P*-wave velocity, and thermal conductivity with increasing depth are not clearly observed at Site U1598. Magnetic susceptibility (MS) is highly variable in volcaniclastic layers and is sometimes very high. The volcanic lapilli of lithostratigraphic Subunit Ic have distinctly lower density than the nonvolcanic, ooze-dominated lithologies of Subunits Ia and Ib. These high values of MS correspond to volcaniclastic layers. Two layers with high *P*-wave velocity, one around 5 mbsf and the other at about 71 mbsf, both correspond to lapilli-ash layers in Hole U1598A. Overall, there is no clear systematic increase in bulk density and *P*-wave velocity with increasing depth. Whether the lack of a signature of compaction is real, a consequence of the limited depth of the holes, or an artefact of drilling and recovery disturbances, cannot be readily determined.

To determine the geochemistry of the volcanic and tuffaceous materials, one tephra sample was handpicked within Hole U1598A. Following cleaning, grinding, fusion, and dissolution, the material was analyzed shipboard for major (Si, Al, Fe, Mg, and Ca), minor (Ti, Mn, Na, K, and P), and trace (Sc, V, Cr, Co, Ni, Cu, Zn, Rb, Sr, Y, Zr, Nb, Ba, Ce, and Nd) elements using inductively coupled plasma–atomic emission spectroscopy (ICP-AES). The volcaniclastic unit sampled was classified as a dacite. Bulk chemistry values are less evolved than glass chemistry as expected due to bulk analyses including both minerals and glass. Concentrations are reported for all analyzed trace elements, but Ce, Cr, Cu, Nb, Ni, P, Rb, S, and V were below detection limits in the majority of samples; volcaniclastic analytical errors are ±1% for major elements and ±5%–10% for trace elements. Trace element ratios were used to discriminate broadly between the volcanic centers of Kolumbo, Santorini, and Christiana.

To determine the inorganic constituents of IW, a total of seven water samples were taken from the mudline and whole-round squeezing of sediment intervals at Site U1598. Aliquots of IW were used for shipboard analyses, and the remaining water was taken for shore-based analysis, following protocols specified by individual scientists. The retrieved pore waters were analyzed shipboard for salinity, alkalinity, pH, major anions (Cl^-, SO_4^{2-}, and Br^-), major cations (Ca^{2+}, Na^+, Mg^{2+}, and K^+), and major (S, Ca, Mg, K, and Na) and minor (B, Ba, Fe, Li, Mn, P, Si, and Sr) elements. Salinity ranged from 40‰ to 70‰.

Headspace gas analyses were performed at a resolution of one sample per full-length core (9.5 m advance) throughout Hole U1598A at Site U1598. The aim was to monitor the presence and abundance of C1–C3 hydrocarbons as part of the standard IODP safety protocol. A total of nine

headspace gas samples from Hole U1598A and three from Hole U1598B were analyzed by gas chromatography (GC). Methane, ethane, and propane concentrations are below the detection limit through all of Site U1598.

Thirty core sections recovered from Hole U1598A were suitable for paleomagnetic analysis using the superconducting rock magnetometer (SRM) system. Alternating field (AF) demagnetization of these sections yielded data at 1592 intervals, with magnetizations generally decaying linearly to the origin following removal of a low-coercivity drilling-induced component after demagnetization at 15 mT. Eight discrete samples were also demagnetized, with all showing normal polarities of magnetization. No reversals are present in the dataset, and the sampled interval is therefore assigned to the Brunhes Chron, which is compatible with available biostratigraphic age constraints.

Due to the instability of the formations encountered, downhole logging was not conducted at Site U1598.